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Heat Transfer Enhancement for Tube in Tube Heat Exchanger Using Twisted Tape Inserts

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Abstract— *Heat transfer augmentation techniques refer to different methods like* Swirl-flow devices *include a number of geometric arrangements or tube inserts for forced flow that create rotating and/or secondary flow. Ccoiled tubes, inlet vortex generators, twisted-tape inserts, and axial core inserts with a screw-type winding used to increase rate of heat transfer without affecting much the overall performance of the system. These techniques are used in heat exchangers which are used in process industries, , air-conditioning equipments, refrigerators thermal Power plants, radiators for space vehicles and automobiles etc. This work mainly focuses on the twisted tape inserts with different pitch and twist ratio and its effect on friction factor.*

Keywords— heat exchanger, swirl flow devices, twisted tapes, twist ratio, pitch, friction factor.

I. INTRODUCTION

Heat exchangers are used in different processes ranging from conversion, utilization & recovery of thermal energy in various industrial, commercial & domestic applications. Some common examples include steam generation, condensation in power & cogeneration plants, sensible heating & cooling in thermal processing of chemical, pharmaceutical & agricultural products, fluid heating in manufacturing & waste heat recovery etc. Increase in heat exchanger's performance can lead to more economical design of heat exchanger which can help to make energy, material & cost savings related to a heat exchange process. The need to increase the thermal performance of heat exchangers, thereby effecting energy, material & cost savings have led to development & use of many techniques termed as heat transfer augmentation. These techniques are also referred as heat transfer enhancement or intensification. Augmentation techniques increase convective heat transfer by reducing the thermal resistance in a heat exchanger. Use of Heat transfer enhancement techniques lead to increase in heat transfer coefficient but at the cost of increase in pressure drop. So, while designing a heat exchanger using any of these techniques, analysis of heat transfer rate & pressure drop has to be done.

Apart from this, issues like long term performance & detailed economic analysis of heat exchanger has to be studied. To achieve high heat transfer rate in an existing or new heat exchanger while taking care of the increased pumping power, several techniques have been proposed in recent years. Twisted tapes a type of passive heat transfer augmentation techniques have shown significantly good results in past studies. For experimental work, different designs of twisted tapes used are typical twisted tape (TT). All these tapes have been studied with three different twist ratios (y = 4.213, 5.337, 6.4606) and depth of cut (d = 6 mm) for notched twisted tapes.

II. LITERATURE REVIEW

Bodius Salam et.al. [1] have investigated the heat transfer enhancement in a tube using rectangular cut twisted tape insert. An experiment was carried for measuring tube side heat transfer coefficient, friction factor, heat transfer enhancement efficiency of water for turbulent flow in a circular tube fitted with rectangular cut twisted tape insert. A copper tube of 26.6 mm ID and 30 mm OD with 900 mm test length was used. A stainless steel rectangular cut twisted tape insert of 5.25 twist ratio was used. The rectangular cut had 8 mm depth and 14 mm width. The Re was varied in the range of 10000 to 19000 with heat flux variation of 14 to 22 kW/m^2 for smooth tube and 23 to 40 kW/m^2 for tube with insert. At comparable Re, Nu in tube with inserts were enhanced by 2.3 to 2.9 times at the cost of increase in the friction factor by 1.4 to 1.8 times compared to that of smooth tube. Heat transfer enhancement efficiencies were found to be in the range of 1.9 to 2.3 and increased with the increase of Re.

S. Naga Sarada et.al [2] have investigated the heat transfer augmentation using twisted tape inserts having different cut sections in a circular tube. It is observed that twisted tape generates swirling flow which causes higher turbulence and greater mixing in the tube. It is proved that as Re increases, Nu increases and friction factor decreases. For all tapes irrespective of their geometry and shape as the twist ratio of the tape increases both Nu and friction factor increases. Heat transfer rate is higher when cuts are provided on the twisted tape insert compared to the plain twisted tape insert and plain tube without insert.

Dnyaneshwar S. Nakate et.al. [3] investigated the performance of heat exchanger using different types of turbulators. It was derived that use of turbulators proved more appreciable in double pipe heat exchangers. A double pipe U bend heat exchanger with water as the cooling fluid

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having a flow rate of 15lit/min was used to cool oil which had a flow rate of 2lit/min. Then a twisted tape of pitch=15cm and length 4m was added to the heat exchanger and the effectiveness was compared. It is computed that twisted tape inserts give 36-48% more heat transfer for full width and 33-39% for reduced width. The enhancement is mainly due to centrifugal forces resulting from the spiral motion of the fluid. The maximum friction factor rise was about 18% for 26mm width and only 17.3% for reduced width inserts. Reduction in the tape width causes reduction in Nusselt number as well as friction factor.

Mukesh P Mangtani et.al.[4] worked on modifications on geometry of twisted tapes in a double pipe heat exchanger. The heat transfer coefficient is found to increase by 40% with half-length twisted tape inserts when compared with plain heat exchangers. The value of heat transfer and friction factor of double pipe heat exchanger can be improved with the help of reduced width twisted tape (RWTT) with three types of different twist ratio (y=3.69, 4.39, 5.525) based on constant flow rate. The heat transfer coefficient was found to be 1.18, 2.61, and 3.58 respectively times the smooth tube values. The heat transfer coefficient and friction factor increases with decrease in twist ratio compared with plain tube. It was derived that the values of Nusselt number, Reynolds number, Prandtl number, pressure drop and friction factor are dependent on the geometries of the twisted tape with different twist ratio, pitch ratio, tape width etc.

Prashant Tikhe et.al [5] have investigated the heat transfer enhancement using twisted tape inserts of different width ratio and under constant wall heat flux condition. The experiments were carried out to determine heat transfer, friction factor and thermal performance characteristics in turbulent flow ($7500 \leq Re \leq 13000$). The tapes of five different width ratios (W/D) of 0.35, 0.44, 0.53, 0.62, and 0.71 at constant twist ratio (H/D) of 2.5. The experimental results show that Nusselt number increases with increasing Reynolds number and increasing width ratio (W/D) of the swirl generators. Also the friction factor decreases with increasing Reynolds number and decreasing width ratio. Nusselt number increased in the ranges of 6.04% to 17.26% compared to the results of the tube without twisted tape depending on the operating conditions. At the same pumping power, the use of twisted tape inserts results in thermal performance factor up to 1.17 times of those of the plain tube.

K. Abdul Hamid et.al. [6] introduced the advance heat transfer fluid called nanofluid which is prepared by dilution technique of Titanium Oxide (TiO2) in based fluid of mixture water and ethylene glycol (EG).

S. Eiamsa-ard et.al. [7] investigated the performance of a heat exchanger using TiO_2-H_2O nanofluid and overlapped dual twisted tapes. The study was carried out using TiO_2 with volume concentrations (ϕ) of 0.07%, 0.14% and 0.21% and (O-DT) with twist ratios (y_o/y) of 1.5, 2.0 and 2.5. The experimental and numerical results indicated that turbulators with small twist ratio delivered strong swirl intensity and high turbulent kinetic energy. The use of overlapped dual twisted tapes (O-DT) at twist ratio 1.5 enhanced heat transfer rate by 89%, friction factor by 5.43 times and thermal performance up to 1.13 times as compared to plain tube. Using ϕ=0.21% and y_o/y=1.5 gave a heat transfer enhancement of about 9.9-11.2% and thermal performance improvement up to 4.5%.

Hafiz Muhammad Ali et.al. [8] focused on the use of water based MgO nanofluid for thermal management of a car radiator. Nanofluid of different volumetric concentrations (i.e. 0.06%, 0.09%, and 0.12%) showed enhancement in heat transfer compared to the pure base fluid. A peak heat transfer enhancement of 31% was obtained at 0.12% volumetric concentration of MgO in base fluid. The fluid flow rate was maintained in a range of 8-16 litre per minute. Lower flow rates resulted in greater heat transfer rates as compared to heat transfer rates at higher flow rates for the same volumetric concentration. Heat transfer rates are weakly dependant on the inlet fluid temperature. An increase in inlet temperature from 56° C to 64° C only showed a maximum 6% increase in heat transfer rate.

A Dewan et.al.[9]have shown that heat transfer passive augmentation are advantageous compared with active techniques, because the insert manufacturing process is simple and these techniques can be easily employed in an existing heat exchanger. In design of compact heat exchangers, passive techniques of heat transfer augmentation can play an important role if a proper passive insert configuration can be selected according to the heat exchanger working condition (both flow and heat transfer conditions). In the past decade, several studies on the passive techniques of heat transfer augmentation have been reported. He has taken review on progress with the passive augmentation techniques in the recent past and will be useful to designers implementing passive augmentation techniques in heat exchange. Twisted tapes, wire coils, ribs, fins, dimples, etc., are the most commonly used passive heat transfer augmentation tools. He emphasized to works dealing with twisted tapes and wire coils because, according to recent studies, these are known to be economic heat transfer augmentation tools. The former insert is found to be suitable in a laminar flow regime and the latter is suitable for turbulent flow. The thermo-hydraulic behaviour of an insert mainly depends on the flow conditions (laminar or turbulent) apart from the insert configurations.

III. TWISTED TAPE INSERTS

The insert used for the experiment are low carbon steel ANSI AS-177 helical twisted tapes. The present work deals with finding the heat transfer coefficient and the friction factor for the twisted tape with twist ratios (p/w=4.213, p/w=5.337, p/w=6.4606).

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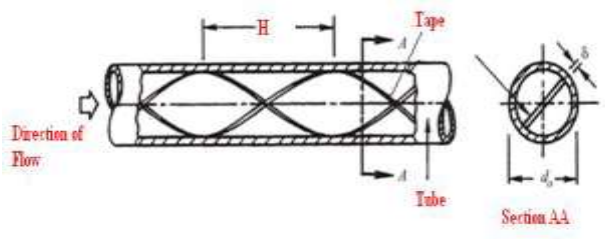

H or p = Pitch of the tape;
d_o = Outer diameter of tube;
δ = Thickness of tape; w = width of tape

IV. EXPERIMENTAL SETUP

A tube in tube heat exchanger consisting of a test section, rotameters, and a tank for supplying hot fluid and a heater for heating water is used for experimentation. The test section is a Plain copper tube with dimensions of 1400 mm length, inner tube-20.4 mm ID, and 25.4 mm OD, wall thickness- 2.5 mm; Outer MS pipe- 45.8 mm ID, 50.8 mm OD and wall thickness- 2.5 mm. Two calibrated rotameters, with the flow range 400 to 1600 LPH, are used to measure the flow of cooling water and hot water. The hot water at operating temperature is drawn from tank by using pump. Similarly a rotameter is provided to control the flow rate of hot water from the pump discharge. Cold water flow rate is varied and hot water is flowed at constant rate. Four RTD sensors measure the inlet & outlet temperature of hot water & cold water (T1, T2, and T3& T4) through a multipoint digital temperature indicator.

The twisted tapes are inserted from one end of the tube and by varying the pitches, the thermal performance of the heat exchanger is analyzed.

V. RESULTS

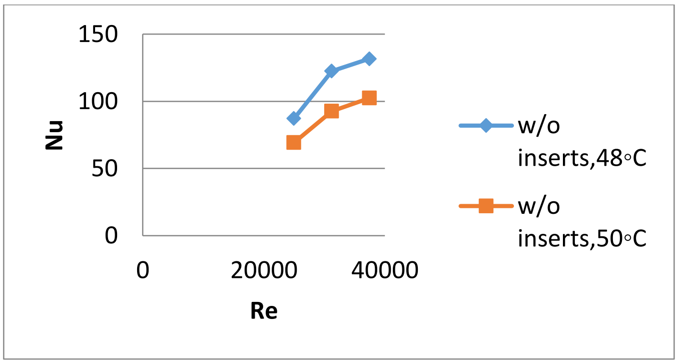

Chart-1: Plot of Nusselt Number Vs Reynolds Number for bulk mean fluid temperatures 48 ℃ & 50 ℃.

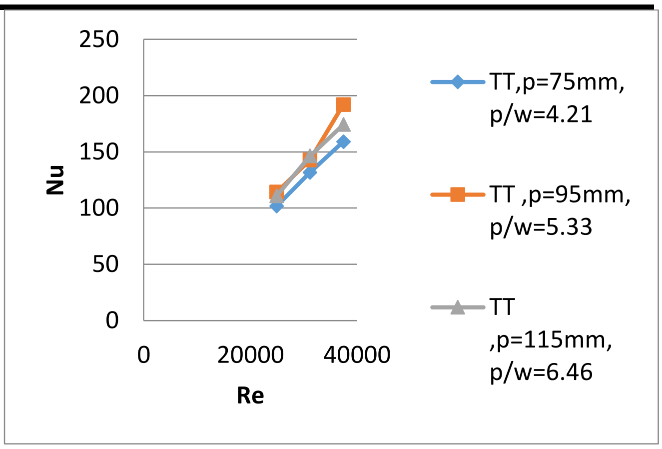

Chart-2: Plot of Nusselt Number Vs Reynolds Number for plain twisted tapes of pitches 75, 95, 115 mm for bulk mean fluid temperature 50 ℃.

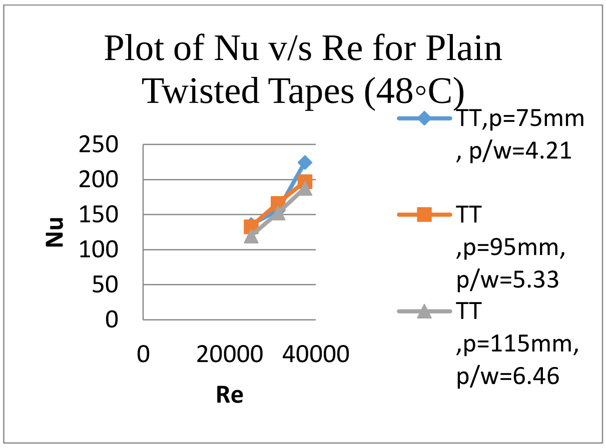

Chart-3: Plot of Nusselt Number Vs Reynolds Number for plain twisted tapes of pitches 75, 95, 115 mm for bulk mean fluid temperature 48 ℃.

Chart 1,2,3 show variation of Nusselt Number with Reynolds Number for plain tube as well as tube with typical twisted tapes. These variations are plotted for various twist ratios (y = p/w). The twist ratios 4.213, 5.337 and 6.4606 are considered. It is observed that Nusselt number is 30 - 45% larger with PTT than that of plain tube arrangement. While the PTT with twist ratio's 4.213 and 5.337 are responsible for the higher Nusselt Number. At the given Reynolds number, the Nusselt number consistently increases with the decrease in twist ratio. This is due to the fact that the tape with smaller twist ratio (y) induces stronger turbulent intensity. In addition, it gives longer flowing path which leads to longer residence time and thus more efficient heat transfer compared to that with larger twist ratio (y).

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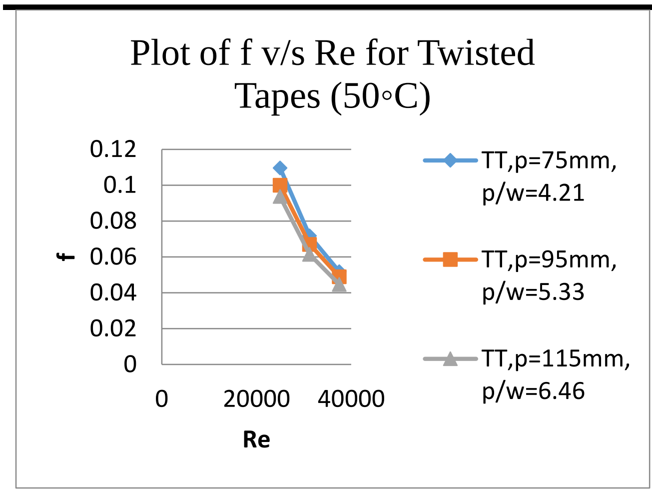

Chart-4: Plot of friction factor (f) Vs Reynolds Number for plain twisted tapes of pitches 75, 95, 115 mm for bulk mean fluid temperature 50 ℃.

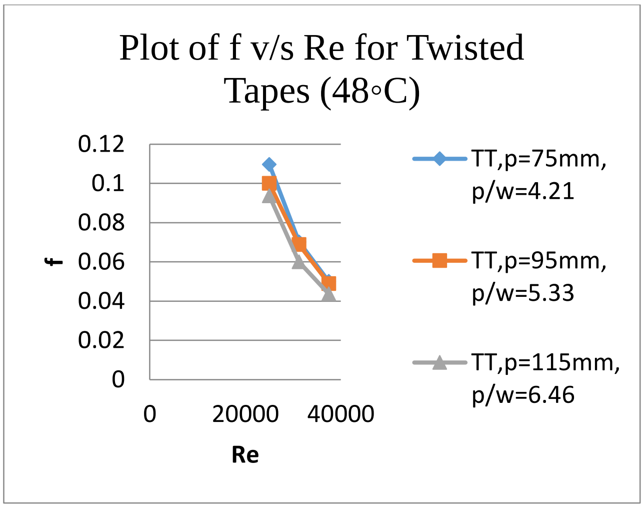

Chart-5: Plot of friction factor (f) Vs Reynolds Number for plain twisted tapes of pitches 75, 95, 115 mm for bulk mean fluid temperature 48 ℃.

Chart 5 and 6 show variation of friction factor with Reynolds number for plain tube, plain and notched helical twisted tapes at various twist ratios (p/w= 4.213, 5.337 and 6.4606). As found, the friction factor decreases with increasing twist ratio (p/w). Because twisted tape with shorter twist length provides longer flowing path, resulting in larger tangential contact between the flowing stream and tube surface. Therefore loss due to the friction increases. Same time the formation of vertex due to twists and notches causes for the large variation in velocity which is also contribute to pressure drop. The larger pressure drop is not desirable. Hence to select the proper insert for heat transfer enhancement, one has to determine the enhancement efficiency which is ratio of Nusselt's number to Friction factor.

VI. CONCLUSIONS

The convective heat transfer performance a flow characteristics of fluids flowing in a double pipe heat exchanger has been theoretically investigated. The effect of Reynolds number on the heat transfer performance and flow behaviour of the fluid has been theoretically determined. Important conclusions are summarized as follows:

1. With increase in twist ratio, Nusselt's Number decreases but at the same time pressure drop also decreases.
2. For same twist ratio, plain twisted tape (TT or PTT) shows greater Nusselt's Number, heat transfer coefficient and friction factor than the value we get for Plain Twisted Tape (PTT).
3. In a heat exchanger, while the inserts can be used to enhance the heat transfer rate, they also bring in an increase in the pressure drop. When the pressure drop increases, the pumping power cost also increases, thereby increasing the operating cost. So depending on the requirement, one of the above mentioned inserts can be used for heat transfer augmentation.

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